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Hydrologic Regimes Control Post-Fire Carbon and Nitrate Export in Mediterranean Climate Mountain Watershed

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Increasing wildfire frequency, size, and severity in Mediterranean-climate regions is altering hydrologic and biogeochemical processes. Yet drivers of the behavior of post-fire elemental export in mountain watersheds remain poorly understood. Explicit coupling of long-term stream water chemistry datasets with watershed-specific hydrologic regimes is needed to link the mobilization and transport of solutes that complicate downstream drinking water treatment.

We developed a multi-year hydro-geochemical dataset with five years of post-fire data from a citizen-science partnership with the American River Conservancy (ARC) and the Rancho Murieta Community Services District and 27 years of pre-fire data from the National Water Quality Monitoring Council. To investigate how hydrologic partitioning regulated dissolved organic carbon (DOC) and nitrate (NO_3^-) export following the 2021 Caldor Fire (burn area: 221,835 acres), we applied the functional flow period (FFP) framework to 113 years of pre-fire USGS streamflow data in the Cosumnes River Watershed (CA, USA).

These data demonstrate that post-fire export responses were strongly streamflow dependent. During wet-season baseflow, atmospheric-river flows increased DOC loads in the first two post-fire years but attenuated by year three, signaling depletion of hillslope organic carbon. Post-fire DOC loads remained elevated during the dry season baseflow for the entirety of the study period but diminished in magnitude after four years. In contrast, NO_3^- loads exhibited delayed but persistent divergence from baseline conditions, remaining elevated beyond four years post-fire. Snowmelt-driven high flows during the spring recession further structured export timing, with peak DOC occurring in the second post-fire year and peak NO_3^- in the fourth.

The behavior of DOC and NO_3^- export indicate decoupled transport pathways and evolving chemical dynamics within the recovering Critical Zone. Shifts in export were impacted more by hydrologic regime transitions than by elapsed time since fire alone. By embedding post-fire stream chemistry within FFP analysis, we elucidated the connectivity between antecedent drought, post-fire atmospheric rivers, and downstream water quality shifts, while yielding insights for watershed management. As wildfire frequency and hydrologic extremes intensify, hydrologic regime-based partitioning of long-term stream chemistry datasets may improve forecasting of post-fire constituent export in fire-prone watersheds that are paramount to our drinking water supply.